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IMPROVING INDUSTRY SCIENCE LINKS THROUGH UNIVERSITY TECHNOLOGY TRANSFER UNITS AN ANALYSIS AND A CASE

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Improving Industry Science Links through University Technology Transfer Units
An Analysis and a Case

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Abstract

Connectivity has become one of the critical success factors in generating and sustaining high-performing National Innovation Systems. Industry Science Links (ISLs) are an important dimension of this connectivity. Over the last decades, multiple insights have been gained (both from theory and practice) as to how "effective" ISLs can be fostered through the design and the development of university-based technology transfer units. In this paper, we document and analyze the evolution of "effective" university-based technology transfer mechanisms, towards a matrix structure allowing an active involvement of the research groups in commercial exploitation of their research findings, while specialized supporting services like intellectual property management and business plan development are centralized. We show that the establishment of:
(1) an appropriate context within academia;
(2) the design of stimulating incentive structures for academic research groups and,
(3) the implementation of appropriate decision and monitoring processes within the interface unit itself,
are critical elements in fostering "effective" linkages between industry and the academic science base.

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1. Introduction

It is now widely recognized in the economic literature that R&D and innovation are a major driver of economic growth. Although the evidence shows that R&D has clear links to productivity performance, the link between R&D and economic growth is complex. Recent economic theories (see Furman et al. (2002), Porter (1990), Romer (1990)) have looked at what determines an economy's "national innovation capacity" defined as the ability of a nation to not only produce new ideas, but also to commercialize a flow of innovative technologies over the longer term. From this perspective, a range of factors are important for "innovation systems" to be effective. The "supply" of R&D (i.e. the amount of R&D carried out, the number of skilled researchers) and the "demand" for innovation (rewarding successful innovators) is a *necessary* but not a *sufficient* condition for a successful innovation system. In particular, broader framework conditions are important as well. Perhaps the most critical element in the framework is the interconnectedness of the agents in the system. Through networking among firms, researchers and governments, the supply of new ideas can diffuse throughout the economy to maximize spillover effects.

The hypothesis that the performance of a (national) economy in terms of innovation and productivity is not only the result of public and private investments in tangibles and intangibles, but that it is also strongly influenced by the character and intensity of the interactions between the elements of the system, is strongly advocated in the literature on "National Innovation Systems" (Freeman (1987), Lundvall (1992), Nelson (1993), Patel & Pavitt (1994)). Innovation and technological development depend increasingly on the ability to utilize new knowledge produced elsewhere and to combine it with the stock of knowledge available. For this purpose, absorptive capacities, transfer capacities and the ability to learn by and through interaction are crucial success factors in innovation (see Cohen & Levinthal (1989 & 1990), Foray & Lundvall (1996)). Novel and commercially useful knowledge is the result of interaction and learning processes among various actors in innovation systems, i.e. producers, users, suppliers, public authorities, and scientific institutions, constituting the so-called "knowledge distribution power" of the system (David & Foray, 1995).

A central issue within the "knowledge distribution power" perspective of an innovation system, are the links between industry and science. Theoretical and empirical work in innovation economics provides support for the use of scientific knowledge by creating and maintaining industry-science relations to positively affect innovation performance (see Kline & Rosenberg (1986), Feller (1990), Rothwell (1992), Rosenberg & Nelson (1994), Dodgson (1994), David & Foray (1995), Mansfield & Lee (1996), Mansfield (1991, 1997), Branscomb et al. (1999), OECD (2000)). But at the same time the empirical evidence, especially for Europe, shows that the flow of basic research into commercial applications is not trouble-free, cf the so-called "European Paradox" (EC (2002)). A better comprehension of industry science links has thus figured high on the policy agenda in many OECD countries. Major benchmarking exercises have been designed in search of effective practices to improve the commercial applications of basic research. (OECD (2002), Polt et al. (2001)).

This paper deals with Industry Science Links (further abbreviated as ISLs), discussing and illustrating the effective practices that have been identified by various exercises to overcome some of the barriers to the commercialization of basic research. Specific attention will be devoted to the use of university technology transfer offices as a mediating institution for improving ISLs. The case of K.U. Leuven Research & Development, the technology transfer office of the Catholic University of Leuven, Belgium, will be used to document the gradual evolution towards a better understanding in the design and the development of effective transfer practices.

2. Industry Science Links

Universities and other public research institutes are increasingly expected to contribute to the economic performance of their home countries. Their role is no longer solely confined to be producers of basic knowledge, but the know-how they generate should also be better and quicker transferred into commercial activities, which lead to the creation of economic welfare. There are some industries where the link between research and innovation is explicit and direct. Industries such as aerospace, biotechnology, microelectronics, pharmaceuticals, organic and food chemistry are "science-based" in the classic sense and have since their inception relied heavily on advances in basic research to feed directly into their innovations. But much innovation derives from "other-than-basic-research" related activities, particularly in the so-called non-science based industries. Nevertheless, even here innovation may be facilitated by a better use of the resources of basic research, for example, the training of skilled researchers, who have the potential to increase the absorptive capacity of an industry. Hence, the interactions between science and industry involve a wide and complex range of knowledge transfer processes, besides the direct transfer of intellectual property from a university to a company.

2.1. A complex phenomenon

"*Industry-Science Links*" hence refer to the different types of interactions between the industry and the science sector that are aimed at the exchange of knowledge and technology. Typically, the following formal forms are considered:

- Collaborative research, i.e. defining and conducting R&D projects jointly by enterprises and science institutions, either on a bi-lateral basis or on a consortium basis;
- Contract research and know-how based consulting by science commissioned by industry;
- Development of Intellectual Property Rights (IPRs) by science both as a tool indicating their technology competence as well as serving as a base for licensing technologies to enterprises while generating lump-sum and royalty payments in return. Those IPRs are not limited to the

establishment of patent portfolios, but also include the protection of design typologies, the establishment of frameworks for Material Transfer Agreements (MTAs), the protection of databases, the property rights on tissue banks, etc.;

- Start-up of technology-oriented enterprises by researchers from the science-base generated at the research institute;
- Co-operation in graduate education such as temporary practical studies at enterprises or the joint supervision of thesis projects;
- Advanced training for employees, i.e. further education for enterprise staff in research and innovation related topics;
- Systematic exchange of research staff between companies and research institutes via internship programs and leave-of-absence assignments.

Behind this multitude of formal relationships lies a myriad of informal contacts, gatekeeping processes, personnel mobility and industry-science networks on a personal or organizational base, including informal consulting and information exchange, alumni meetings, mutual memberships in advisory boards, sponsoring of professorships by industry, etc. These informal contacts and human capital flows are ways of exchanging knowledge between enterprises and public research, which are more difficult to quantify, but nevertheless extremely important and often a catalyst for instigating further formal contacts (see Allen (1977) or Matkin (1990)).

2.2. A phenomenon on the rise

The recent intensification of the interaction and co-operations between universities and industry owes much to the following interrelated factors (see OECD 2000):

- Increasing budgetary stringency forces policy makers to make tough choices in the allocation of resources that affect the science system. Universities and other public research institutions are forced to seek external sources of income and are thereby encouraged to carry out research work financed by industry. Indeed there is a clear trend of a growing share of funding of HERD by the business sector while the total public share is steadily declining (see Table 1).

Table 1: Higher Education RD expenditures (HERD) by Funding Source 1983 - 1997 for 7 EU countries [b]

	Total public share of HERD funding	Of which: General university funds (GUF)	Business share of HERD funding
1983	94.0	68.3	2.9
1989	89.9	60.2	5.4
1993	87.7	60.1	5.8
1997	84.6	57.9	6.4

b: Denmark, France, Germany, Italy, Ireland, the Netherlands, UK
Figures represent weighted averages.
Source: OECD (2000)

- In view of the speed and scope of technological change, and the increasing complexity and multidisciplinary nature of research, even the largest corporations require more and more information from beyond their boundaries when developing and implementing their innovation strategies. With firms relying more extensively on external linkages, public science is one of the external sources where firms are looking for rapid and privileged access to new knowledge. Mowery (1998) identifies as a major change in the US innovation system an "increased reliance by US firms on sources of R&D outside their organizational boundaries, through such mechanisms as … collaboration with US universities…." The increased use of public science by firms can be documented in the number of references to scientific publications in patents. Narin et al. (1997) for instance and more recently Verbeek et al. (2001) have shown that the number of such references has nearly tripled in the nineties, although they are still highly concentrated within a limited number of patent classes.
- So called "science-based technologies" (biotechnology, information technologies, new materials) are defined as fields with frequent references to scientific knowledge. Especially these science-based technologies are strong contributors to technological progress, as for instance observed through the increasing share in patents in these fields. The growing importance of science-based technologies partly explains the growing number of citations of scientific literature in patent documents (Schibany et al. (1999), Verbeek et al. (2001)).

2.3. A hampered phenomenon

Industry Science Links are part of the National Innovation Capacity and as such they require as necessary conditions, both a demand and supply for such links, as well as an institutional context in which those demand-supply conditions can thrive. The demand for Industry-Science Links requires the active presence of innovation strategies in the enterprise sector (Pavitt (1998)), which in turn require market incentives for innovators to engage in new technologies and apply new scientific knowledge. This often requires the presence of large, domestic corporations in high-tech areas representing an own R&D potential that provides the resources needed to interact with science. Smaller high-tech firms often play a complementary role on the demand side. They indeed fill a gap by their willingness to assume more risky innovation strategies that sometimes run against the going concern present in the large R&D intensive firms. The necessity to have a high absorptive capacity to effectively link with science holds a fortiori for smaller innovative firms. It is not astonishing then that quite a lot of those smaller innovative firms have emerged directly out of scientific activity. This assures them right from the start of the absorptive capacity needed. As a consequence, there exists a dynamic complementarity between large R&D intensive firms and smaller high-tech firms as to generating a demand for Industry-Science Links.

The supply factor for Industry-Science Links relates to a well performing and competitive science base. The science base should cover a sufficiently wide portfolio of scientific fields in which research excellence is fostered.

A match of knowledge supply and demand provides a necessary condition for establishing ISLs in innovation activities. But even if there is supply and demand for ISL, effective industry-science interactions may not materialize. The extent to which this potential is utilized depends on the barriers inside an innovation system. ISLs can be hampered by a lack in qualified personnel or in financing sources. Additionally, a partners' lack of understanding each other's culture and conflicting objectives among partners may impede good industry science relations, notably the conflict of interest between the dissemination of new research findings versus the commercial appropriation of new knowledge. Also, unfavorable incentive structures may hamper ISLs, such as research evaluation schemes solely oriented towards academic criteria, short-term orientation in enterprise strategies... But also systemic failures of the market for know-how, besieged by high transaction costs, uncertainty, information asymmetries, and a lack in transparency impede ISL.

Governments realize the systemic failures in economy-wide knowledge generation and diffusion. Favorable institutional conditions are put in place to remove the barriers inherent in ISL. These include legislation and regulation, including the regulation of property rights, a consistent science and technology policy but also a general culture favorable to ISL.

3. Management of ISL from the perspective of the Science Base

Along the supply side of the industry-science "knowledge market", there are various types of institutions actives such as universities and other higher education institutions as well as publicly funded research organizations. The organizational composition of the science base "landscape" is an important variable determining the performance of the public research sector, since each of the types mentioned has its own views and policies on ISLs. Universities cultivate industry contacts to ensure additional financing, allowing to expand their research capabilities beyond what core funding would allow and to secure good job prospects for their students. Leading research universities have even more ambitious goals and seek ISLs to consolidate their position in innovation networks and to obtain and maintain a strategic position in the knowledge market. But universities need to balance the quest for ISL with their teaching and basic research mission. Publicly funded research organizations, especially the specialized organizations with an applied research mission, have developed their linkages with the relevant industries almost organically. In many instances, the intensity and the frequency of those linkages is often seen as a direct performance indicator for those publicly funded research organizations.

Since science-based innovations increasingly have a multidisciplinary character and build on "difficult-to-codify" people-based interactions, university-based systems of ISLs, which combine research with a broader education mission, are seen as enjoying a comparative advantage relative to research institutes (OECD, 2001). Policy makers have consequently been shifting attention towards universities to improve the commercialization of basic research.

Academic institutions are called upon to assume multiple roles in society. From institutions of education they have evolved towards research institutions where new fields of science and technology can emerge. Their role as poles for new scientific and technological development is well-recognized today and public authorities demand from their university system to deliver value for money in the increasingly competitive world of science and technology. Research output is continuously assessed and funding is made contingent upon the quality of the research performed. Individual researchers as well as complete research groups and institutes are evaluated and assessed at regular intervals. A dominant design of research performance definition, assessment and monitoring has emerged. This should ensure scientific excellence as the breeding ground for scientific novelty and breakthroughs that fuel the innovation process in industry.

But universities are demanded not only to play an active role in science and technology development, but also increasingly to turn those developments into useful innovations whenever possible and desirable. Given the generic problems for established firms in bringing new technologies to the market, universities are increasingly looked upon as a source of incubators for knowledge transfer through new venture creation. Spinning off companies from (basic) research is the entrepreneurial route to commercialize public research. It attracts a great deal of policy attention in the current wave of start-ups and new venture creation in many countries. Assessing the spin-off formation rate is often seen as a key indicator for the quality of ISLs (OECD, 2001).

New technology ventures originating at universities assume a bridging function between curiosity-driven academic research on the one hand and strategy-driven corporate research on the other hand. These new ventures have the potential to introduce technological disequilibria that change the rules of competition in existing industries. They allow for a multitude of experiments with often-competing "dominant designs" and "business models," only a few of which will ultimately survive. Hence, new ventures are the gene pool from which new industries may emerge in the longer run (Roberts (1991), Utterback (1994), Thurow (1999)). Academic entrepreneurship in biotechnology is probably the most striking example when it comes to describing these phenomena. Universities can play an important role in this process, as they can be a breeding ground for new venture creation.

Universities, to alleviate at least some of the budgetary pressures that arise in maintaining research program continuity, welcome the economic potential of closer ISLs. However, as the economic pressure on academic research grows, universities have to cope with how they reconcile both the "exogenous" (i.e. curiosity-driven invention) and "endogenous" (i.e. market-driven innovation) component of the academic research community/enterprise. Gearing up academic R&D toward exploitation avenues therefore requires an appropriate <u>context</u>, <u>structure</u> and <u>processes</u> within the university. This should incite the researchers' involvement in the commercial applications of their findings, so that the fundamental values of research and teaching are complemented rather than hampered, by the university's active engagement and involvement in the emerging processes of industrial and entrepreneurial innovation and knowledge transfer.

<u>Context</u> is related to the institutional and policy environment, the culture and the history that has unfolded within the academic institution. It shapes and configures the norms, values and attitudes of academic researchers towards combining "curiosity-driven" research and actively seeking for "market-relevant" opportunities that originate from this same research. **<u>Process</u>** relates to the day-to-day operations of knowledge creation and innovation management within the academic environment.

Processes central to managing academic R&D toward commercial exploitation are knowledge management and new venture creation. **Structure** provides for appropriate incentive and organizational mechanisms.

In terms of incentive mechanisms, the structure of intellectual property rights and the evaluation system are important. The *ownership of IPRs* creates strong incentives for universities to look for commercial applications of their research. While ownership of publicly funded research has been shifted from the state to the research sector, the allocation of ownership within the research sector (i.e. between the institution and the individual researcher) remains a more unsettled issue. Given the high coordination costs of managing, enforcing and exploiting IPRs, ownership is often left to the research organization. But to ensure the researcher's interests in commercialization, he or she should enjoy a fair share of any resulting lump-sum payments or royalties. *Evaluations of researchers* should not be exclusively based on research criteria, but take into account that excellence in research and teaching has become, at least partly, more tied to applications in industry.

In terms of organizational structure, *decentralization* is important. Creating more responsiveness from universities towards ISLs requires that public authorities should give universities sufficient autonomy and freedom to develop their research policy and relations with industry. Also inside the university organization, decentralization is important. Creating a *specialized and decentralized technology transfer office* within the university is instrumental to secure a sufficient level of autonomy for developing relations with industry. This provides a better "buffer" against possible conflicts of interest between the commercialization and the research and teaching activities. A dedicated transfer unit also allows for specialization in supporting services, most notably management of intellectual property and business development. A higher degree of financial and managerial independence further facilitates relations with third parties, such as venture capitalists, investment bankers and patent attorneys. There is, of course, always the issue of scale as smaller universities often lack the resources and technical skills to effectively support such organizational arrangements and investments. And, at the same time, a separate unit needs to be able to maintain close enough relationships with the researchers in the different departments.

Different organizational arrangements within the university may result in different propensities to engage in the commercial exploitation of the university's (basic) research. If the university opts for an organizational arrangement known as the *professional bureaucracy*, marked by traditional faculty and departmental organizational boundaries and structures, one can assume the university's commercial orientation to be limited. Obviously, universities that organize their activities solely along disciplinary lines show little strategic intent to engage in the commercialization of their research results.

As the strategic intent to exploit their (basic) research commercially develops and grows, universities may find their traditional disciplinary boundaries and departmentalization unfit for setting up linkages with industry. Most often, the second step in the evolution towards the development of full-fledged ISLs then consist in the creation of a divisional structure whose sole mission is the exploitation of the know-how and intellectual property of the university. This approach often results in the university setting up a *division for research exploitation* or a holding structure. The advantage of this type of set-up is that it clearly demonstrates the strategic intent of the university to commercialize and to allow economies of scale in supporting services. The disadvantage, however, is that such a divisional structure very often generates new boundaries within the institution, making a smooth integration of an activity portfolio consisting of basic research, education and commercial exploitation of research at the level of the research groups difficult. In other words, divisional structures and set-ups may demonstrate the institution's strategic intent towards commercial exploitation, though it often lacks the decentralized approaches and incentive mechanisms that are required to engage and involve the researchers and their groups as active partners in the exploitation process.

A next step in the evolution towards more professional ISL development is the creation of a *matrix structure* within the institution. Such a matrix structure allows the research groups to be actively involved and engaged in the commercial exploitation of their own research findings. In a matrix structure, the aforementioned Division of Research Exploitation indeed becomes decentralized and integrated within the research groups themselves. Only a minimal central technical support infrastructure remains that assists the decentralized divisional structure(s) with issues like intellectual property management, contract drafting and negotiation, and business plan development for spin-off creation. By adopting a matrix structure, the university assumes a high degree of commercial orientation since it does not only unveil its strategic intent to commercialize (basic) research findings, but it also directly incentivates its researchers and their groups to participate in the process. Indeed, in such a matrix structure, accountability (both with respect to revenue and expense generation) is located at the level of the research group, which should act as a direct incentive for the researchers themselves to actively manage and grow their portfolio of explorative and exploitative research activities.

4. ISL Benchmarking exercises: In search of effective practices

Fuelled by the notion that smooth interaction between science and industry becomes more important for the success of innovation activities and ultimate economic growth, ISLs are a central concern in many government policies in recent years. Significant institutional barriers to the commercialization of research still exist (OECD (2000), EC (2002)). Especially in Europe, there is a perceived gap between high scientific performance on the one hand and industrial competitiveness on the other hand. The underperformance of the E.U. relative to the U.S. seems to be not so much situated at the level of the supply of basic research, but at the level of getting the new ideas transformed into commercial success. To tackle the "European Paradox," major benchmarking exercises are set up in the E.U. in search of effective practices to improve the commercialization of the E.U. science base. But also in the U.S., which is typically praised for its superior ISL performance relative to the E.U., the search for good practices in ISL have received ample attention (see e.g. Branscomb et al. (1999), Siegel et al. (2001)). This section reviews the main conclusions from these exercises first on improving ISL in general (section 4.1) and subsequently zooming in on best practices at universities (section 4.2) and at technology transfer offices (section 4.3).

4.1. Effective practices for ISL

Viewing ISLs as a part of the Innovation Capacity of a nation implies that high levels of ISLs require a high-tech orientation at the industry side and a performing and well-incentivized science base, with specialization in science-based technologies. Benchmarking industry-science relationships in the E.U., Polt (2001) concludes in line with the "European Paradox" doctrine, that within the E.U. insufficient ISLs typically do not reflect a lack in supply of scientific knowledge. Low levels of ISLs in E.U. member states can be attributed mainly to a lack in demand at the enterprise side, i.e. a specialization on innovation paths that do not require scientific knowledge or expertise and to a lack of incentive structures and institutional factors at the science side. In addition, Hall, Link & Scott (2001) provide qualitative evidence of the U.S. of intellectual property barriers that inhibit the formation of public-private research partnerships.

Another critical success factor, which Polt (2001) indicates as favorable for high levels of ISLs in a country is the presence of ISL policies which are embedded in a *coherent technology policy* strategy designed to improve *all* elements of the national innovation system. Effective public support for ISLs needs a long-term approach as it attempts to change structural features of innovation systems and traditional attitudes and behavior of actors. Also a favorable overall "climate" towards ISLs, i.e. cultural attitudes and public acknowledgement, is important.

4.2. Effective practices for establishing ISLs at universities

To get universities engaged in ISL, there need to be well developed incentive schemes in place, balancing all major missions of science, i.e. education, fundamental research and applied research. Important is an explicit industry orientation of science as specified in the institutional mission and objectives. With respect to universities that want to improve their industry link, the following practices have been identified in various exercises as facilitating a high level of interaction (Polt (2001), OECD (2000)). They relate to both the knowledge supply and knowledge transfer capacities of universities.

In terms of <u>knowledge development</u>, reaching scientific excellence in research is a necessary first condition for ISL. Attractiveness for industrial partners demands competence at universities both in short-term oriented R&D and in long-term oriented strategic research. Developing scientific excellence requires the presence of the necessary resources related to personnel qualification and capabilities, as well as a clear research orientation and research mission of the university. More particularly, obtaining scientific excellence in those disciplines that link to science-based technologies like biotechnology, life sciences, nanotechnology and ICT will create a high demand for ISLs.

The main competitive advantage of universities in the knowledge market is their competence in generating new findings and new approaches to problem solving. It is highly important that this basic R&D competence is directly available within the same research group or department that is engaged in joint R&D with and transfer activities to enterprises. Thus, research units should be involved in both types of basic and applied research, but not necessarily each individual researcher in the team at the same time. A good team structure allows exploiting the complementarity between basic and applied research, with basic research enhancing the efficiency of applied research, but also applied research providing positive feedback for basic research. Also teaching and applied research may be mutually reinforcing activities with graduates providing the necessary contacts and absorptive capacity for applied research with industry and an applied research profile of the university attracting students. A university that can exploit the complementarity between teaching, basic and applied research will thus be a strong player in the knowledge market.

Focusing on knowledge transfer capacities, exercises to improve ISL at universities are especially successful when they implement ISLs as a central component of the institutions' mission, and consider the ISL activities in researcher evaluations, providing both individual and organizational incentives. A joint public-private set-up in terms of ownership, financing or advisory and steering board also stimulates industry contacts, but is no precondition for successful transfer activities (Polt (2001)).

Universities that are successfully engaged in ISLs do not solely rely on contract research with industry. Rather, they show a balanced financing consisting of a portfolio of financing by the government for long-term oriented, fundamental research, of industry financing in the course of contract research and collaborative R&D projects, and of competition-based public financing, including funds for joint research with other, often more basic research oriented, public science institutions. A sufficiently wide portfolio of different ISLs is important not only from a financial risk and diversification point of view, but also in view of the complementarity between the different modes of ISLs. Patents for instance, may become much more important when viewed not in isolation as a mere source of income from royalties, but as a negotiation chip in sponsored research contracts with industry (see e.g. Thursby et al., 2001). In the mix of ISL mechanisms, contacts and networking are key, underscoring the importance of personnel mobility between industry and science (see also Van Dierdonck et al., 1990).

Bercovitz et al. (2001) based on a sample of US universities provide evidence of the importance of the organizational structure set up within universities for linking up with industry. Universities with a high record in ISLs, i.e. with high volumes of contract research, patents and licensing income, most often apply a decentralized model of technology transfer, i.e. the responsibilities for transfer activities are located at the level of research groups and individuals.

Associated with a decentralized model is the provision of adequate managerial support and know-how that allows the researcher to concentrate on R&D efforts and knowledge exchange, thus supporting a matrix structure approach. This leaves most managerial activities associated with transfer activities (such as legal agreements, financial issues, management of intellectual property, business plan set-up, etc.) within a central technical support infrastructure. This support should definitely include the field of commercialization of R&D results via patenting and licensing where specific legal and market know-how is needed.

4.3. Effective practices at specialized technology transfer offices

In many countries, *specialized technology transfer offices* have been established either at universities or within public research laboratories as an instrument to improve ISLs. Technology transfer offices at universities operate next to other intermediaries such as technology and innovation consultants for SMEs, technology and science parks, incubators, information provision systems and contact platforms. Nevertheless, there is no clear evidence on the effectiveness of these intermediaries and their role in ISLs (Polt, 2001). Sometimes, the transfer office itself might even integrate several of those activities along the transfer value chain. While there is no doubt that comprehensive intermediary structures foster ISLs to some extent, a clear effective practice model is missing. Most of the critical success factors for ISLs (such as appropriate incentive schemes and institutional settings, the level and orientation of R&D activities at both industry and science, legislation) cannot be shaped by the intermediaries themselves. They therefore often will fail to foster ISLs if there exists other barriers to interaction.

In the E.U., most intermediary organizations are rather small and are therefore often below the necessary critical mass to stimulate ISLs effectively (Polt, 2001). Criticism concerning publicly financed intermediaries concentrate on the following issues:

- The number of intermediaries is often too large and their supply of services is difficult to survey and often not known to the target group;
- Many intermediaries do not specialize on certain services but attempt to provide a package of supportive services which often does not correspond to their resources;
- Public intermediaries may disturb competition from a growing supply of private intermediary services;
- Intermediaries that are not well embedded either within the science base or the company may lack the proximity necessary to create the effective interactions at the researcher level that stimulate and sustain the collaborative efforts characteristic of ISLs.

Within the universe of intermediary structures, *university technology offices*, at least some of them, seem to be more effective. Factors that distinguish these units from less successful peers are (Polt, 2001):

- their focus on combining basic and applied research within research teams, regularly auditing the research strategy of the group in order to cope with changes in economy and society;

- the direct transfer between researchers and industry (i.e. avoiding intermediaries);
- their day-to-day proximity to the researchers themselves;
- their emphasis on building the complementary assets needed for the research groups to be effective in their ISLs (contract law, IPRs, spin-off development, access to venture capital, ...), and
- the design of sufficiently attractive individual remuneration packages that reward successful transfer activities.

An activity profile that specializes on specific science-based technologies and on own commercialization avenues through spin-offs further characterizes these successful units.

Further evidence from the U.S. in terms of good practices for technology transfer units is provided in Siegel et al. (1999). Based on interviews at five major research universities, the authors identify several critical organizational factors for university technology transfer offices. The most prominent ones are: adequate faculty tenure, promotion policies, royalty and equity distribution systems, as well as the staffing practices within transfer offices, requiring a mix of scientists, lawyers and managers acting within a highly professional environment. They furthermore indicate as an important skill for technology officers a "boundary spanning" role, serving as a bridge between the firms and scientists.

5. University technology transfer units as a mechanism to improve ISLs: The case of K.U. Leuven Research & Development

The various evaluation studies provide support for the matrix structure approach to adequately deal with ISLs in universities, since this organizational structure allows integration of ISL activities within the research groups, incentivation and specialization of critical support services. The transfer unit of the K.U. Leuven, Leuven Research & Development, is one of the intermediary institutions identified as promising approach in the E.U. benchmarking exercise (Polt, 2001). The next section will detail the context, structure and processes that explain the performance of K.U. Leuven Research & Development. But since the demand and supply for ISL, as well as the institutional framework, shape the prospects for a technology transfer unit to effectively link science and industry, we first briefly sketch the characteristics of the Belgian innovation system in sections 5.1-5.2, before we zoom in on the practices within Leuven Research & Development in section 5.3.

5.1. ISLs in Belgium

In terms of knowledge production structures, relevant for ISLs, Belgium does not belong to the group of countries, which are considered to be top, such as Finland, Sweden and the US. Overall, Belgium's R&D expenditures as a % of GDP is below EU average both in terms of what the private and public sector is spending (Capron & Meeusen (2000)). In Table 4, we summarize the main characteristics of the indicators relevant to the Belgian ISLs.

Table 4: ISL relevant RTD structure

Indicator	*Belgium*	*Germany*	*Sweden*	*USA*
Characteristics of R&D expenditures				
BERD in % of GDP	1.06	1.63	2.77	1.95
HERD in % of GDP	0.43	0.40	0.80	0.36
GOVERD (incl. non-profit private) in % of GDP	0.08	0.34	0.13	0.28
Share of HERD financed outside GUF in %	65	33	49	> 80
Share of HERD financed by industry in %	10.6	9.7	4.5	6.0
Direct government funding of BERD in ‰ of GDP	0.47	1.47	2.11	2.81
Structure of innovation at industry				
Share of BERD performed in high-tech in %	30	32	37	45
Share of BERD performed in medium- to high-tech in %	41	54	37	25
Share of continuously R&D performing small manufacturing enterprises (20-50 employees) (1996)	33	27	34	n.a.
Share of small manuf. ent. having applied for a patent (1996)	19	17	22	n.a.
RTD Performance				
Number of high-tech patents per 1 mill. Population (1998)	16	24	42	20
Impact factor of scientific publications in natural sciences (citations per publication) (1995-99)	4.7	4.9	5.1	6.7
Impact factor of scientific publications in engineering (citations per publication) (1995-99)	1.9	1.8	1.9	2.0

Shaded areas indicate above EU average

If no year is given, data refer to the latest year available for each country, which is either 1997, 1998 or 1999.

Source: On the basis of Polt (2001)

5.1.1. The demand for ISLs: The structure of enterprises

As in most countries, the majority of R&D expenditures is accounted for by the enterprise sector (BERD, Business Expenditures on R&D). As Table 4 shows, Belgium has a less pronounced high-tech orientation of industry. It specializes in the higher segments of medium-tech industries, such as engineering & machinery, chemicals, vehicles, electrical machinery, metals and base materials. It is fair to characterize the Belgian enterprise sector as being more oriented towards the rapid adoption of new (process) technologies, rather than towards the genesis of new technology breakthroughs. Another possible drawback in terms of industry structure for fostering ISLs is the large percentage of affiliates of multinational firms in the "large enterprise" sector. Although there is a large share of small to medium sized firms in Belgium, the small sized firms seem to be more innovation active as compared to their typical E.U. counterpart (Polt 2001)).

5.1.2. The supply side to ISLs: The structure of the science base

On the supply side, Belgium seems to own a well performing science base, at least in terms of the quality of the publications generated by Belgian scientists (see Table 4). Belgium invests a relatively large amount in R&D at higher education institutions (HEIs), most notably in its 17 universities, among which K.U. Leuven is the largest. As detailed in Table 4, universities are highly dependent on external sources for funding, mostly acquired on a competitive basis. In terms of the structure of funding for public research, basic funding via the General University Funds accounts for only one third of the total R&D expenditures by universities. In Belgium, universities receive relatively more funding from the business sector than in most other E.U. countries.

Beside the university system, Belgium has several public (or semi-public) research institutes (PSREs) with varying objectives, structures and size. In total, their significance in the public science sector is limited, but some institutions are highly specialized on ISLs activities and therefore play an important role for industry-science links. In order to foster technology transfer to science-based industries, many PSREs specialize on certain technologies and establish dense networks to the enterprises in the respective fields of technology. Their main mission is to support innovation by conducting both strategic and applied research, including a large fraction of joint R&D projects. Especially in Flanders, these institutions play an important role in the regional innovation system. The two most prominent are IMEC and VIB[2].

Another major feature of the Belgian ISL system is the huge variety of intermediaries, both public and private, attempting to foster ISLs. They include next to commercialization offices at universities, special research institutions, public financing institutions, incubators, business and innovation centers, information services, and technology consultants. Most experts feel that there are too many intermediaries to be efficient (Polt, 2001).

5.1.3. The institutional framework for ISLs in Belgium

The federal-regional political system in Belgium introduces a high level of complexity that impedes the development of a consistent policy promoting ISLs. In Belgium, the public promotion of ISLs is therefore less significant, both in volumes and influence upon ISLs (Polt, 2001). Nevertheless, there are some programs established in recent years to stimulate ISL. Interface offices which universities are developing to improve their ISLs, receive some public support from the regional

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[2] IMEC, the Interuniversity Microelectronics Center (founded in 1984 as a spin-off from the Electrotechnical department of K.U. Leuven) operates is in the field of microelectronics, conducting research and promoting technology transfer and stimulating spin-offs. IMEC is located on the K.U. Leuven Campus. VIB, Flanders Interuniversity Institute for Biotechnology (founded in 1995), mission is to promote biotechnology in a broad sense (research and development, technology transfer including stimulating spin-offs, and public awareness of biotechnology). VIB combines eight university departments and five associated laboratories. K.U. Leuven is one of the members.

governments, both in Wallonia and Flanders. Nevertheless, many of these interfaces are too small to be efficient, although there are some effective practice examples, notably in Leuven (Polt, 2001).

The legal basis for research contracts between universities and third parties was established in Flanders in 1991 and was complemented by the Decree of 22 February 1995. This states that all costs directly linked to the execution of contract research, namely the use of infrastructure, services or personnel from the university are at the expense of the principal of the contract. It also determines that all research contracts have to be approved by the university administration. There are no other regulations for Flemish universities, so that most of them have their own internal regulations that arrange and monitor these matters. These internal regulations determine the minimum overhead costs that must be applied in these contracts, the method of payment and the possibility of personal remuneration for researchers.

Intellectual property rights belong to the policy area of the Communities in Belgium. In Flanders, the Decree of 22 February 1995 determined that research results that can lead to valorization (including patents, licenses and other IPR) must be divided between the university or research center and the principal of the contract, and that each individual contract includes the results of negotiations between parties. Article 103 of the Decree of 29 August 1998 determines that IPR from research carried out by university researchers belongs to the university. This leaves out the possibility for researchers to obtain the rights to their own research results, unless the university fails to exploit these results within a time span of 3 years. For research financed by the Community, the Community still owns the rights but agrees since a number of years to let the university exploit its research results.

The Decree of 1995 also determines the criteria that need to be fulfilled before a university can invest in spin-offs. Financial participation is only possible if the research results that lead to the creation of a spin-off, and other intangibles, are valorized. The university can accept shares in exchange for these intangibles, but it can never own the majority of voting rights. The university is further entitled to participate in specialized venture funds that are created to support this financial participation.

5.1.4. The performance of Belgium in terms of ISL

The relatively low R&D budgets both at the enterprise and the public science sector would predict low levels of ISLs in Belgium. Nevertheless, the overall picture for ISLs in Belgium exceeds these expectations. Table 4 has already shown how the Belgian enterprise sector plays a comparatively significant role in financing university research. This indicates that the enterprise sector has the absorption capacity as well as the willingness to contract out research to the science sector, which can be related to their good scientific performance.

Table 5: ISLs in Belgium

Indicator	Belgium	EU
Cooperation in innovation projects		
Innovative manuf. enterprises co-operating with HEIs in %	13.4	9.7
Innovative manuf. enterprises co-operating with PSREs in %	8.5	8.3
Innovative service enterprises co-operating with HEIs in %	15.3	6.4
Innovative service enterprises co-operating with PSREs in %	5.9	7.0
Science as an information source for innovation		
HEIs used as inform. source by innov. manuf. enterpr. in %	6.7	4.2
PSREs used as inform. source by innov. manuf. enterpr. in %	4.8	2.6
Conferences, meetings & publications used as inform. source by innov. manuf. enterpr.	5.4	7.6
HEIs used as inform. source by innov. service enterpr. in %	2.0	4.4
PSREs used as inform. source by innov. serv. enterpr. in %	2.7	3.2
Conferences, meetings & publications used as inform. source by innov. serv. enterpr.	13.7	15.3

Source: Newcronos, CISII, 1996

The number of innovating enterprises that have cooperative agreements with universities is much higher in Belgium as compared to the EU average, as is shown in Table 5. This holds both across manufacturing and services and despite a lower presence of Belgian firms in typical science based industries. Cooperative agreements with PSREs is less frequent compared to HEIs, which is surprising, given the specific mission of most of these institutions, but can be related to the minor overall importance of these institutions in the Belgian science system as well as to their rather young age. A similar picture can be observed when using science as an information source in innovation projects. Although in line with other countries, public science is not a major source of information for innovating enterprises, innovative enterprises in Belgium, at least in manufacturing, rely more strongly on new research results achieved at public science, compared to EU standards.

Table 6 reports the most recent patent grants to Belgian public science institutions at the USPTO over the period 1990-2000. More than half of the patents originates from PSREs, which is not surprising given their specific mission. Among universities, the K.U. Leuven is the most active in terms of granted patents in the USPTO system. Similar results, also with higher absolute numbers, are obtained when analyzing EPO patents. No information is available on income from royalties for HEIs.

Table 6: Number of patents granted by the USPTO to different Belgian non-market institutions between 1990 and 2000

Name of institution	Number of patent grants
Interuniversitair Microelektronica Centrem (IMEC)	107
Subtotal Belgian Public Research Institutions	**132**
K.U. Leuven via Leuven R&D	51
Subtotal Belgian Universities	**94**
Total Belgian USPTO patent grants	**232**

In terms of research based start-ups of enterprises, Belgium is performing quite well according to E.U. standards. According to a study by Degroof et al. (2001), the number of spin-off enterprises has increased exponentially in Flanders since the mid-nineties and in Wallonia as well since the end of the 1990s. The increase in number of spin-offs can be accounted for by the interplay of several factors, including the presence of pre-seed capital funds, some successful and visible IPOs in the mid-1990s and late-1990s. Also, the development of university interface services and the creation of Business Angel networks has helped in creating a spin-off culture. Finally, changes in the Belgian legislative framework made it easier and less ambiguous to start up companies for academics.

5.2. The Katholieke Universiteit Leuven: ISLs as a mission

Founded in 1425, the K.U. Leuven is the oldest and largest university in Flanders and Belgium, encompassing all academic disciplines. It has the legal status of a private institution, but receives 85% of its funding from the Belgian Government, both in a direct and in an indirect competitive way. More than 1.400 tenured professors and 3.500 researchers are currently employed at K.U. Leuven, dealing with a student population of more than 25.000 students each year. The mission statement of the K.U. Leuven stresses three basic activities. The university ensures the transfer of knowledge from generation to generation through its teaching activities, it performs fundamental research, and it provides services to the community by making its inventions and knowledge available to society and to companies. "As a university it is an academic institution where research that opens up new horizons and knowledge transfer are both essential and complementary." (K.U. Leuven, Mission Statement, 2002).

The second and third tasks have been promoted and supported by two specialized units. The Research Coordination Office deals with basic research: designing the basic research policy of the university, taking care of inter and intra university research funding and research evaluation. The third mission deals with contract research, patents, spin-offs and research parks and is organized via K.U. Leuven Research and Development. The total research budget of the KUL amounted to 165 million Euro in 2001 of which 26% (43.5 million Euro) was derived via LRD. Of this total research budget, 55% goes to research in exact sciences, 25% to biomedical sciences and 20% to humanities.

K.U. Leuven's research efforts and output have increased considerably over the past few years, both quantitatively and qualitatively, thus positioning K.U. Leuven at the forefront of European universities. It recorded in 1999, 2343 publications in international peer-reviewed scientific journals. A total of 15% of these publications where in journals with an impact factor above 4. The spearhead expertise of its researchers is thus the foundation for successful collaboration. The following domains are specific areas of excellence: Biotechnology, Electronic & Mechanical Engineering, Environment, Food Sciences & Technology, Medicine & Medical Research, European Integration and Materials Sciences & Technology.

5.3. K.U. Leuven Research & Development: Generating economic welfare through academic R&D

Being embedded in the largest university in the Belgian Innovation System, K.U. Leuven Research & Development (further abbreviated as LRD) was founded in 1972 to manage the industry component of the university's R&D portfolio. What started as a minor fraction of the total university R&D activity has, over the past 29 years, grown into a significant portion of the university's total R&D portfolio and employing 24 support staff professionals. It has evolved from a specialized division towards a matrix structure, operating a number of specialized supporting services closely integrated with its research groups. In line with Ed Roberts' (1991) and Lester Thurow's (1999) insights on wealth creation through technology entrepreneurship, K.U. Leuven R&D has stimulated the exploitation of the university's research through a rich mix of mechanisms stimulating entrepreneurial behavior within its many research divisions.

5.3.1. The institutional framework of LRD

The fact that LRD now exists for 29 years is not to be neglected at all. This "long" history indeed implies that, by now, several generations of faculty and researchers have developed and built their careers alongside the presence of -and often based on- active interaction with LRD. As a consequence, the "cultural" impact of the historic embeddedness of LRD within the university is not to be underestimated. This historic presence is perhaps the single most important learning effect that has occurred within the university as to academic involvement in the processes of knowledge transfer for industrial and entrepreneurial innovation. It has enabled several generations of faculty and staff to become acquainted with industrial innovation; to understand its strengths and weaknesses; and to evaluate the benefits of academic entrepreneurship as a complement to the more traditional and established processes of industrial innovation. Hence, time and history are an integral part of the context that enables LRD to leverage the management and transfer of academic R&D at K.U. Leuven.

From its start, K.U. Leuven Research & Development has received a large amount of budgetary and human resource management autonomy within the university. This implies that LRD, although being fully integrated within the university, manages its own budgets as well as the research personnel employed on those budgets. From an incentive point of view, creating a context with such high levels of budgetary and human resource autonomy is critical, since this allows for flexibility and degrees of freedom to operate that are often lacking within the "traditional" university administration. This autonomy, although highly necessary, also introduces a "creative tension" within the university itself. LRD indeed thereby operates at the crossroads of academic and business value systems.

The context of freedom to develop ISLs, has to be embedded in a proper organizational approach. Therefore, LRD introduced the organizational concept of the "*research division.*" Researchers belonging to different departments at the university, even belonging to different faculties, can decide to join forces and to integrate the commercial-industrial component of their knowledge portfolio in a research division at LRD. As a consequence, the research division concept introduces a "de facto" interdisciplinary matrix structure within the university. This, of course, does not happen without any tensions given the "professional bureaucracies" that universities normally are. Today there exist 40 divisions, supported by about 220 faculty members and employing about 480 researchers, scattered across the various faculties and departments of the university. It is obvious that not all faculties are equally represented and involved. The majority of LRD activities stem from the divisions belonging to the engineering (54%), bio-medical (24%), biosciences (9%) and the sciences (7%) faculty. The humanities are underrepresented, although their activities via LRD have been increasing over the last five-year period.

To ensure close contacts between LRD and the research groups, a group of *innovation coordinators* is established. The innovation coordinators are paid by LRD on a part-time basis (on average 20% of their salary) to act as a permanent liaison officer between LRD and its divisions. The rest of their time is spent as a researcher or junior faculty within one of the LRD divisions.

Whereas the <u>incentive system</u> within the departments and faculties is promotion along the academic ladder, mainly based on the assessment of research quality and teaching ability, the LRD divisions have developed an incentive system that is based on budgetary flexibility and financial autonomy. LRD divisions enjoy complete autonomy as to balancing revenue and expenses from their ISL activities. In other words, LRD divisions are entitled to accumulate financial reserves based on the benefits they generate via ISLs. This is quite a unique situation, as most universities tend to centralize the profits generated via ISLs. The decentralized "modus operandi" that exists within LRD therefore acts as an incentive mechanism in and off itself. LRD divisions furthermore are entitled to participate both intellectually and financially in the spin-off companies that they have grown and developed. Finally, besides the aforementioned financial incentive mechanism at the level of the research division, incentives are given to individual researchers as well. Three types of incentive mechanisms at the individual level exist. First of all, researchers are entitled to salary supplements based on the net proceeds from their contract research and consultancy activities. Second, in case of lump sum and royalty payments proceeding from license agreements, individual researchers are entitled to receive up to 30% of the income generated (after expenses have been recuperated). Third, in case of spin-off creation, individual researchers can receive up to 40% of the intellectual property shares (i.e. the IP stock or founder shares) in exchange for the input of their know-how and goodwill. If they wish, they can also invest financially in the spin-off and will hence obtain a pro rata share in the common stock (capital shares) of the company.

This system thus implies that the university has created a matrix structure: research excellence prevails along the hierarchical lines of the faculties and their respective departments, whereas excellence in entrepreneurial and industrial innovation is rewarded along the lines of the LRD divisions. This structure, with sufficient degrees of coordination between academic research and innovation, as well as guaranteeing sufficient autonomy to the faculty and staff engaged in entrepreneurial and industrial innovation activities, is the basis of the university's approach towards managing academic science and technology towards commercial exploitation. This is in line with the matrix model described in Section 3 of this paper. In addition, the dual incentive mechanism is at the core of a management process that enables the university to maintain a balance and a healthy tension between striving for scientific excellence on the one hand, and gearing this excellence towards application and innovation on the other hand.

5.3.2. The activity profile of LRD

A distinct feature of LRD is the broad scope of its activity portfolio. Over time, LRD has developed three major activity poles that underpin its role in managing academic R&D as a business. Within its matrix structure, these central activities concentrate on contract drafting and negotiations, intellectual property management and business plan development. The first, and historically the oldest one, is the contract research pole. Over the years, LRD has grown to provide almost a quarter of the university's R&D budget via contract research activities. As will further become clear, those contract research activities have now reached significant levels both in terms of the volume and in terms of the quality of the work performed. LRD has developed and implemented the necessary processes for financial and personnel management that should support these activities. Also, the legal and intellectual property mechanisms that should underpin these activities are in place. A central LRD staff of 24 professionals assists the research groups with these activities.

The second activity pole consists of managing the university's intellectual property portfolio. This activity was first formally started in 1999 (although it existed organically well before that date), with the creation of an internal intellectual property liaison office and the establishment of a network of formal collaborations with different European patent attorneys. Internal procedures and the necessary information infrastructure were created to support this activity. Finally, a patent fund was established to help research groups cover the initial costs and expenses related to their patenting needs. At the moment, there is a portfolio of about 125 patents (including both granted patents and pending applications). Given the differences between academic and industrial knowledge and patent portfolios, the first criterion deployed by LRD in generating and developing the university's knowledge portfolio is "selectivity." The interest is not so much in generating a large portfolio of patents as in developing a valuable portfolio of patents. A full-time, in-house staff of 4.5 professionals (3 of them holding Ph.D. degrees), complemented by long-term collaborations with a major patent attorney, supports this activity.

The third activity pole concerns the transfer of knowledge via the creation of spin-off companies. Here, LRD has developed the necessary mechanisms and processes that assist in business development and raising venture capital.

The university, in partnership with two major Belgian banks, created its own seed capital fund in 1997, i.e. the Gemma Frisius-Fonds, which has access to 12.5 million Euro in (pre-) seed capital to fund start-up companies that exploit university-based know-how. By the end of 2001, Gemma Frisius had invested 8.8 million Euro in 15 spin-off companies. In July 2002, Gemma Frisius II was created with the same partners, pursuing similar opportunities as its predecessor fund, operating according to the same investment policies and principles. The first fund at present only does follow-on investments in its established portfolio. Both funds are ten-year closed-end funds that operate according to standard venture capital market principles. There is however no separate Investment Company as LRD together with two investment managers from both banking partners form the investment committee of Gemma Frisius. This investment committee does the day-to-day management of the Fund and proposes major decisions to the Board of the Fund. The Board of the university is at all times informed on the investment policy and has statutory rights to intervene in case the Fund would violate basic university policy or the rules set by the government Decree. Both versions of the Gemma Frisius Fund have the same shareholder structure: each banking partner owns 40% of the shares, K.U. Leuven R&D owns the remaining 20%.

In order to assist the start-up entrepreneur, LRD also has access to an "Innovation & Incubation Center" that is jointly owned and operated by the university and the local regional development agency. Accommodation and managerial support for its spin-offs is provided through this "Innovation & Incubation Center," which is located on the Campus and as such promotes close proximity with university laboratories and research units.

In addition a Science Park is available in the close vicinity of the K.U. Leuven which is open for new innovative companies. This park not only houses spin-offs of universities and other research institutions, but also the R&D departments of existing companies. Two new science Parks are currently under construction, in close collaboration with the City of Leuven and the development agencies of the Province.

5.3.3. Finding the Right Mix of Mechanisms: Structure Meets Process

Even with several generations of academic researchers involved in knowledge transfer, a university still has to find and balance the right mix of transfer and innovation mechanisms in order to be performing. At LRD, this mix of structural mechanisms and processes has been designed and developed over time. The following processes can be seen as critical in the success of LRD:

(1) A well-balanced system to manage and monitor contract research in the area of industrial innovation. This system includes the necessary know-how and processes for legal, financial and human resources management as to the volume of research contracts generated via LRD. A central staff of 24 collaborators, assisted by innovation coordinators in the divisions, has grown in expertise and experience over time. Especially the innovation coordinators have a critical task, acting as a liaison officer between LRD and its divisions. Processes to support the activities of the innovation coordinators and to generate trust with the faculty and the researchers they are serving require continuous attention on behalf of the LRD management team. Therefore, appropriate coordination mechanisms such as innovation coordinator meetings and proper training for innovation coordinators to be effective, have been created;

(2) An active knowledge management policy, including a patent fund and an intellectual property advisory group, has been established. The patent fund has been created to support financially those divisions that lack the means to set up their own patent portfolio. This set-up gains in expertise and experience as more cases are developed and managed. As stated before, the core criterion is one of selectivity in admitting new cases to the university's patent portfolio. To this end, the necessary mechanisms, tools and processes have been created to screen for novelty and inventiveness, to do a quick scan of the know-how's economic potential and to eventually assist the research groups in writing the patent and its claim structure. Once again, a lot of attention is paid to train and to educate researchers all over the university so that they become acquainted with the many intricacies of the process of managing their knowledge portfolios;

(3) A venture fund has been created (see above), including an advisory group, to assist academic entrepreneurs in creating their enterprise, taking into account up-to-date principles and best practices on corporate governance. A major focus of the LRD venture unit is to assist the entrepreneurs, first in developing their business plan, then into turning the business plan into a solid business model. Finding a proper funding structure, as well as the right management team, figures high on the agenda of the LRD venture unit.

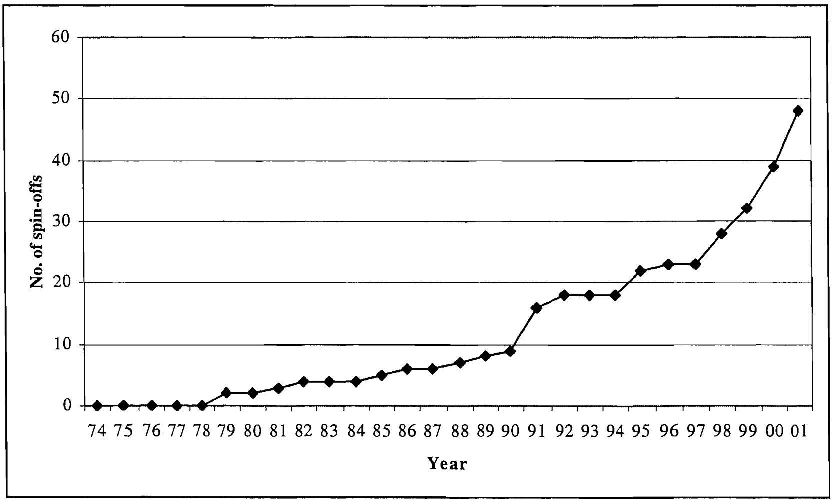
(4) Finally, in 1999, Leuven.Inc was established which acts as a network organization bringing together "like-minded people" from academic research groups, entrepreneurial start-ups, supporting services such as consultancy and venture capital, and established companies in the Leuven area. The aim of Leuven.Inc is to support and to stimulate the exchange of business experiences between its members. To this end, events, opportunities for informal networking, information and training sessions are continuously being organized and generated. Leuven.Inc has close ties to the Cambridge Network. Besides the more personal and informal linkages, the Leuven.Inc website is hosted by the same platform as the Cambridge Network website.

5.3.4. The performance profile of LRD

This mix of mechanisms, tools and processes has enabled the university to generate an increasing flux of knowledge transfer contracts, patents, know-how licenses and spin-offs. By the end of 2001, annual amounts of contract research activities are about 40 million Euro and patent income is steadily on the rise. In 2001, the patent income of K.U. Leuven patents amounted to 2.5 million Euro. This amount is expected to increase significantly over the coming years given a major license agreement between a pharmaceutical company and one of the research groups.

At the end of 2001, the university had a portfolio of 48 spin-off companies. They are distributed across a wide variety of knowledge domains, ranging from mechanical and electrical engineering to bio- and life sciences. Their product-markets are as diverse as automotive, Internet security, 3D modeling, rapid prototyping, stress management and tissue engineering. In Figure 3, we provide an overview of the evolution in the university's spin-off portfolio.

Figure 3: Evolution of K.U. Leuven R&D spin-off portfolio



When taking into account the structure of the present spin-off "deal-flow," it is expected to result in a steady state of 5-to-10 new spin-off creations per year for the coming five years at least. By the end of 2000, these spin-offs generated a turnover of 350 million Euro and employed over 2000 people. Two spin-offs have realized a successful IPO on Nasdaq and Easdaq. There have been two failures. However, as the companies all exploit university technology (and thus engage in active knowledge transfer from the university to the company), the highest failure rate occurs during the phase of spin-off creation. More than half of the projects never makes it to the actual stage of spin-off incorporation.

More profound analyses of the performance and activities of the research divisions show:

(1) Over the years, only 10% of the LRD activities, in which the LRD research divisions are engaged, can be labeled as consulting or routine analyses. The bulk of the contractual LRD activities have evolved towards applied research and knowledge development for industrial purposes. In other words, over the years, the LRD divisions have not only grown with respect to the volume of their contract research activities, but they have also maintained a high standard of quality as far as the content of their LRD activities is concerned;

(2) In addition, the bibliometric performance of the research divisions is strongly correlated with the (monetary) volume of the industrial innovation activities in which they are involved via LRD, thus further corroborating the complementarity between basic and applied research and the remarks on both volume and quality of the LRD activities mentioned supra;

(3) Finally, the top-performers in terms of academic research and industrial contract volumes also tend to be amongst the top-generators of new technology ventures, further supporting the importance of a broad scope of complementarity activities in the activity profile of a technology transfer unit.

6. Conclusion

In this paper, the context, the structure and the processes that universities can use to become active players in the game of managing and applying academic science, technology and innovation from an exploitation perspective have been discussed and reviewed. The development of these three elements needs careful attention and subtle support on behalf of the university's management as well as of the institutional context in which universities are embedded. In addition, time is an important factor in shaping the "right" culture for effective technology transfer and learning as to how to optimize the various transfer mechanisms and monitoring processes through experimentation. Both are needed to transform the awareness of the university's potential contribution to innovation into an appropriate and acceptable context and structure within the university itself that allows this contribution to be effectively implemented.

As we have discussed in this paper, the appropriate context has to be created both at the level of the university and at the level of the institutional context in which the transfer activities are embedded. *Transparent and unambiguous regulations* with respect to ownership titles and property rights are an important element in this respect. Creating the appropriate mix of *incentive mechanisms*, targeted to the research groups as well as to the individual researchers (allowing them to participate in the rewards and the proceeds from their transfer activities) is another critical success factor. As the exploitation of research findings requires extra efforts and risk-taking on behalf of the academic researchers themselves, these efforts should be recognized and rewarded properly. This has led to schemes where researchers and their groups can, for instance, appropriate a significant portion of the royalty streams that are generated on the basis of their inventions. Or, still, it has stimulated the liaison or interface office to elaborate schemes in which researchers and the groups with which they are affiliated receive a significant portion of the shares in a start-up company based on the findings of their research. Finally, academic authorities should accept that this approach could only succeed with a *decentralized management* style within their institution. Decentralization implies sufficient freedom to engage and to operate for the researchers and their groups whenever transfer opportunities occur. Decentralization also implies that the research groups are pivotal in deciding how the proceeds from their exploitation activities will be used. Finally, decentralization also stimulates the research groups to compete with their findings and results in the market for exploitation and innovation.

As this transformation from mere awareness to hands-on implementation occurs, universities further have to play an active role in shaping their internal institutional contexts and structures to enhance and foster ISLs. This implies that universities should be willing to provide the degrees of freedom required within the context just described. More specifically, providing the interface or liaison units with the necessary incentives to professionalize alongside with the degrees of autonomy critical to engage in transfer opportunities when they occur, are key policy steps. As we have discussed in this paper, this professionalization should be accompanied by the necessary structural arrangements within the university. A matrix structure, integrating but yet differentiating exploitation and curiosity-driven academic exploration, was presented as a good structure that allows a university to perform well along both the dimension of scientific invention as well as the dimension of technoscientific innovation.

Finally, these structural arrangements should be complemented with the necessary decision and monitoring processes. These processes first and mainly play at the level of the interface or liaison unit. First, a well-balanced process to manage and to monitor contract research in the area of industrial innovation is a critical issue. This includes the necessary know-how and processes for legal, financial and human resources management pertaining to the volume of research contracts generated via the liaison office. A central staff of professional collaborators has to support this process. Appropriate coordination processes with the research groups, such as innovation meetings and proper training for researchers to be effective in technology transfer, have to be in place. Second, an active knowledge management policy, including a patent funding mechanism and an intellectual property management advisory group, is yet another element in the day-to-day operational processes of the liaison unit. This set-up gains in expertise and experience as more cases are developed and managed. Once again, a lot of attention should be paid to train and to educate researchers all over the university so that they become acquainted with the many intricacies of the process of managing their knowledge portfolios. Third, the availability of and the access to venture funding is highly desired, including a process to monitor the transition from invention to business plan to company start-up, so as to assist academic entrepreneurs in creating their enterprise, taking into account up-to-date principles and best practices on corporate governance. A major focus of the venture unit of a liaison office is to assist the entrepreneurs, first in developing their business plan, then into growing the business plan into a solid business model. Finding a proper funding structure, as well as the right management team, figures high on the agenda of such a venture unit. In order to further assist the start-up entrepreneur, access to physical infrastructure of an Incubation Centre proves to be an asset. Finally, the liaison unit may provide the necessary opportunities for networking amongst its entrepreneuers and academics alike by creating network fora and opportunities to meet.

A matrix structure, integrating the supporting functions for technology transfer management with the organizational structure of autonomous and incentivized research divisions, and all this coupled to a 30-year experience, has done a remarkable job to manage the exploitation of the academic knowledge portfolio at K.U. Leuven. Assistance and funding have helped in this process, though they cannot act as a substitute for the ambition, the strategic thinking and the drive for implementation of the researchers themselves. For academics, those lessons may be the hardest ones to learn since they require them to continuously move between processes of "thinking" and acts of "doing." This duality (or paradox) should be at the heart of the evolving concept of knowledge management at the university.

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